THE FOOD VALUE OF DAUCUS C[illegible]VA

BY

ERNEST PAUL LEWIS

B. S. Purdue University, 19[illegible]

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE IN HORTICULTURE
IN THE GRADUATE SCHOOL OF THE UNIVERSITY
OF ILLINOIS, 1922

URBANA, ILLINOIS

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May 31, 1922

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Ernest Paul Lewis

ENTITLED The Food Value of Daucus Carota and Pastinaca Sativa

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science in Horticulture

J. W. Lloyd
In Charge of Thesis

J. C. Blair
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Recommendation concurred in*

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*Required for doctor's degree but not for master's

THE FOOD VALUE OF DAUCUS CAROTA
AND PASTINACA SATIVA.

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THE FOOD VALUE OF DAUCUS CAROTA AND PASTINACA SATIVA.

I. INTRODUCTION.

Vegetables may be divided into three general classes, depending on their composition. The first class includes those containing a relatively high percentage of protein, the tissue and muscle building material. Beans and peas are common examples of this class. The second, or carbohydrate group, producing energy, heat, and fat, include those having large amounts of sugar and starch and are represented by potatoes and corn. The third group are the succulent vegetables containing a large amout of water.

Carrots (Daucus carota) and parsnips (Pastinaca sativa) both belong to that class of vegetables called the succulent root crops, so-called because of the high percentage of water in the edible part. Carrots contain from 87-93 per cent water and parsnips 80-84 per cent, most of the solid material being carbohydrate in the form of sugar and starch. The succulent roots have been developed from wild forms, and as a result of this development, their size has increased and their texture and quality improved. A. L. de Vilmorin, by the selective process continued through several generations, obtained from the slender-rooted wild form (Daucus carota), biennial plants having thick fleshy roots resembling those of the ordinary cultivated types of to-day. Professor J. Buckman is said to have raised the large hollow-crowned "Student" parsnip from the small-rooted wild type by a similar process of selection.

Both carrots and parsnips can be stored for months without serious deterioration and for this reason are popular

as winter vegetables.However as the season advances the roots are liable to become tough and the quality is impaired unless they are stored under ideal conditions.

There are numerous varieties of carrots under cultivation,most of which differ either in color or shape of root and in the time of maturity.The earliest varieties are very short, some almost globular,while the best of them have very little heart or core.The later varieties are as a rule long and tapering.Some have considerable core ,while others have almost none.

From earlier times the central cylinder or core was supposed to be of a woody texture and very much lower in nutritive value.and it was always the endeavor of the plant breeder to obtain a relatively wide cylinder of bast with a small core.This variation in the size of the core suggested the study of the relative proportion of core to cortex in the various varieties of carrots and parsnips under cultivation.Furthermore,since there was very little evidence to support the popular belief that the central cylinder of carrots and parsnips is very inferior in nutritive value,a study of the relative composition of the core and cortex was made in order to throw further light on the subject.

It has been the purpose of the author to bring together all of the material dealing with the food value of carrots and parsnips and substantiate this data by chemical analyses of the two crops.To this end the roots were grown in the summer of 1921 and submitted to analysis the following winter.

II.HISTORY OF CARROT AND PARSNIP.

The carrot has been in cultivation for two thousand years.It is mentioned by Pliny,and the wild carrot was

known to the Greek writers by 500 B.C.,who spoke of it as being of great service as a stomachic when eaten either in the raw or cooked state.

The carrot was introduced into China from western Asia about 1280.The first mention of its use in Europe was in 1536.It seems probable that the horticultural improvement of the species began in Holland,and it is said that the cultivated forms were introduced from Holland into the gardens of England during the reign of Queen Elizabeth.The first mention of the use of the carrot in England was made by Gerarde in 1597.It has recieved more attention in France than in any other country,and there is reason to believe that it was esteemed there as early as the first century.In the United States carrots were mentioned as occurring in Margarita Island,1565,in Virginia,1609,and in Massachuttes,1629.

The parsnip was undoubtedly known to the Greeks and Romans long before the date of the earliest records show.Quite a confusion of names existed between the carrot and the parsnip. Plinydescribes the medicinal virtue of the elophoboscon,which is supposed to have been the parsnip,and says it was much esteemed as a food.The earliest record of its use in Germany was made by Fuchsins in 1542.

In England the long parsnips were in general use in 1683 and the short round ones in 1634.They were considered a sweet delicacy.The parsnip was probably introduced into America by the earliest colonists.It was mentioned as occurring at Margarita Island by Hawkins in 1564 and cultivated in Virginia in 1609.

III. EXTENT OF USE IN UNITED STATES AND OTHER COUNTRIES.

Carrots are grown commercially in all parts of the United States. According to the census of 1910, the ten leading states in the production of carrots, ranking in the order named are, New York Massachuttes, California, Illinois, Michigan, New Jersey, Louisana, Pennsylvania, Washington, and South Carolina. In the United States some 2,008 farms reported raising more than one acre each in 1909, and the total area of carrots grown was 3,764 acres. The total value of the crop was $473,499.

Parsnips are much less important than carrots. The total value of the crop in 1909 was $102,000, grown on 722 acres, and distributed over 436 farms, making an average of 1.66 acres per farm. Massachuttes produced 30% and New York 23% of the crop. The figures quoted on both carrots and parsnips do not take into account those grown for home use and on commercial plantings of less than one acre. Large quantities of both crops are grown in both of these areas

France probably ranks first among the European countries in the use of carrots and more attention has been paid to the improvement of the crop in that country. In England in 1882 it was stated that the cultivation of carrots and parsnips was gaining from year to year. At present over 11,000 acres are cultivated in Great Britian, the principle counties being Cambridge, Lincoln, and Bedford. In Germany the carrot is chopped and dried to be used as a substitute for coffee. Carrots are very useful in culinary practice for soups, stews, and salads and as this class of cooking has never been reasonably popular in the United States this vegetable has not recieved the attention it deserves.

There are many who believe the roots of this parsley group, including carrots, parsnips, and celery, to be poisonous and if eaten end in sickness, and sometimes death; others believe that parsnips if allowed to remain in the ground until spring and growth starts a poisonous element is produced. The former belief may be well groundedas the wild forms of parsnips and related plants are often poisonous and cases have been reported on infection from handling celery foliage.

IV. STRUCTURE.

The structural characteristics of an edible root, or any portion of a plant which is edible, are a large amount of thin walled nutritive tissue and a small proportion of thick walled tissue. The latter - wood cells and mechanical cells - cannot be entirely dispensed with since they are necessary to the life of the plant, but the nutritive tissue may be largely increased by selection and breeding.

The entire framework of the young carrot is made up of cell walls. Early in the growth of the plant, wood cells begin to develop. The wood cells grow into a fiberous substance. It is the woody fiber and the thickening and hardening of the tissue that make poorly grown or stale vegetables tough and indigestible.

A cross section of a carrot or parsnip root shows two well defined layers, an outer and an inner layer or core which frequently differs from the cortex in color. The proportion existing between the two layers is variable, depending chiefly on the variety. These two parts have a well defined line of division and are easily separated one from the other.

A microscopic examination shows the central cylinder to be composed of two parts, one innermost region made up of pithy substance and an outer region containing the conductive cells. Just outside the core are two rows of thick walled sclerotic cells. The cortex is made up of thin walled parenchmya cells which are smaller more compact and usually darker in color. The epidermis is composed of three rows of cells very similar in form to the sclerotic cells.

If the important food nutrients are stored in larger amounts in the cortex than in the core, the proportion of the two parts has an important bearing on the food value of the root. The larger the proportion of core the smaller the amount of nutrient is contained in the root. The author made a detailed study of the structure and proportion of the core and cortex of 23 varieties of commercially grown carrots in order to determine the exact proportion and to what degree they varied both in the different varieties and among individual roots of the same variety. The first 17 varieties were obtained from American seedsmen and grown in the garden from April 15/1921 to September 27, 1921. Number 18 was planted July 23, 1921, and grown under irrigation until September 27, 1921, so that it had a short quick growing season. Number 19 was an American variety and 20, 21, 22, 23, were French varieties. Number 19 to 23, inclusive, were sown and harvested in the greenhouse.

In order to determine the per cent of core, the author measured the diameter of the core and entire root of a great many specimens of the 23 varieties. It was found that the existing ratio of core to cortex was the same at the top and bottom as in the center so that a cross section at any point gave the same results. The core and cortex may be represented by two circles one inside the other and since the areas of two circles are to each other as

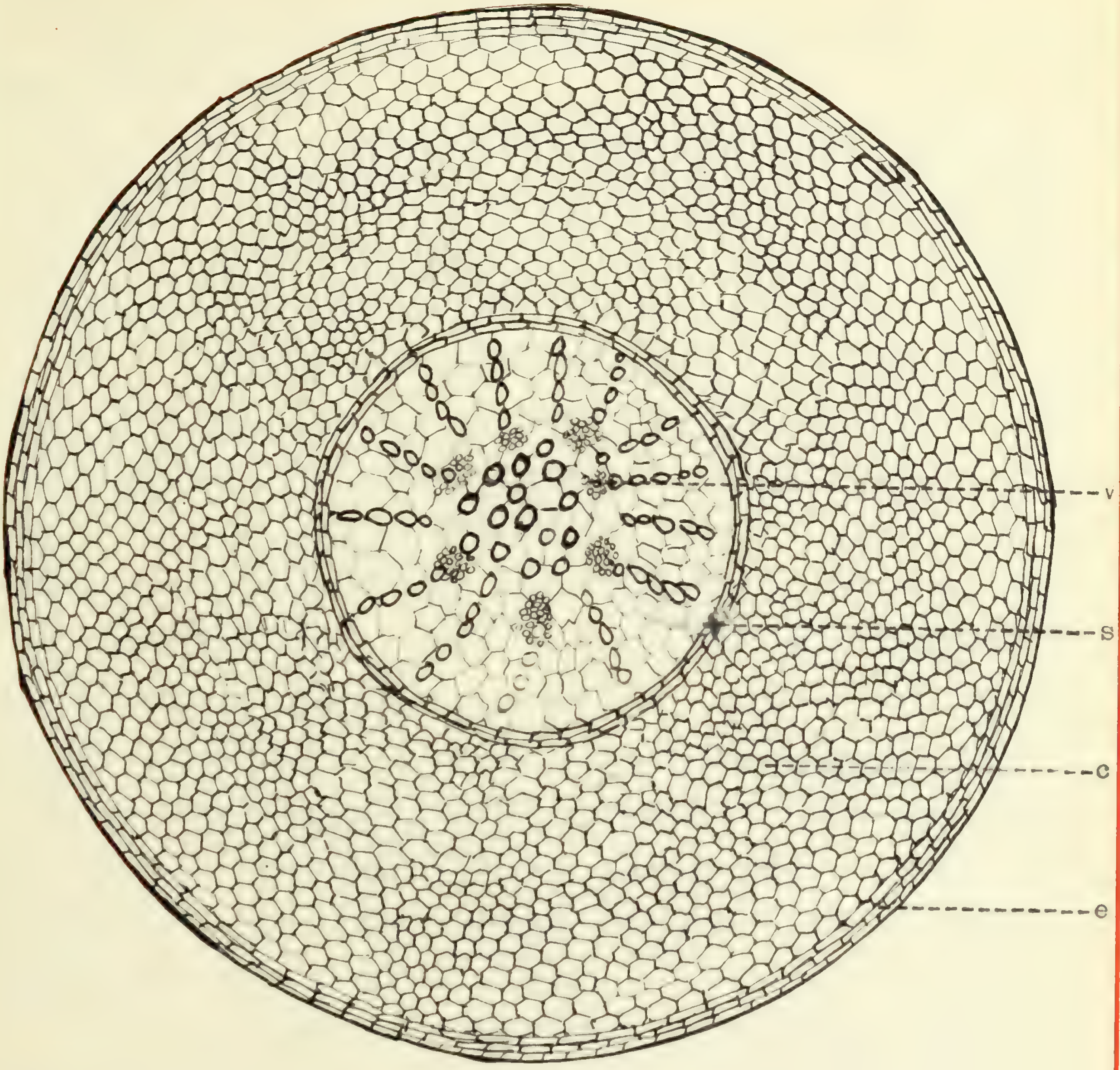

Figure 1.

Cross section of a parsnip. (1)

v - conductive vessels(xylem and phloem)
s - thick-walled sclerotic cells
c - cortical parenchyma
e - epidermis

(1) The carrot is very similar in structure to the parsnip.

the squares of their diameters,the square of the diameter of the core divided by the square of the diameter of the entire root gives the per cent of core.

Tables I and II give a summarized result of these measurements.Table I shows a great variation in the per cent of core in the 23 different varieties and table II the variation in the individuals of the same variety(Henderson's Coreless).

The great variation in the size of the core shows what can be accomplished by selection.The carrot is more important in France than in the United States and more attention has been paid to its improvement as shown by the smaller core in the four French varieties.It might also be added that the flavor and texture of these varieties was superior to most of the American varieties but this might be due in part to the fact that they were forced in the greenhouse and not grown out of doors.Many of the American varieties were advertised under the name of "coreless"and claimed to be devoid of core and fiberous material .However in most cases the core was large and in one so-called"coreless"variety the core constituted over half the total root.

The results show that there is great need of improvement in order to reduce the size of the core.The only question is whether the reduction in the size of the core which contains the conductive tissue,will have any material effect on the growth of the root.No correlation was made between the size of core and total size of root in this experiment.This would be interesting to work out as well as the proportional increase in size of the core and cortex,as the season advances.It seems to be a fact that the core becomes more fiberous and tough with age and it is very reasonable that the proportion of core might also become larger with age.

Table I.

Proportion of Core to Cortex in Different Varieties.

Variety of carrot	No.	Average percent of core: D of root in.	D of core in.	% core %	Extreme variations: Max. %	Min. %
1 Salzer's Coreless	20	1.8	1.2	44.44	56.72	21.36
2 Early Market	20	.5	.25	38.44	43.21	18.27
3 San Jose Champion	20	1.0	.69	47.61	53.28	24.00
4 St. Valery	20	.88	.5	32.28	36.81	21.4
5 Early Golden Ball	20	1.06	.75	50.00	57.6	30.25
6 Half long Nantes	20	.62.	.38	36.00	43.21	19.20
7 Oxheart	20	.88	.69	61.6	67.21	30.25
8 Chantenay	20	.75	.5	44.64	55.10	23.2
9 Early Scarlet Horn	20	.88	.56	40.49	45.10	21.00
10 Imp. long Orange	20	.5	.25	54.4	46.28	18.72
11 Los Angeles Market	20	.62	.37	35.84	43.21	20.26
12 Kelway	20	.75	.5	44.64	55.10	22.36
13 Pride of the Market	20	1.0	.69	47.61	57.10	30.22
14 Coreless	20	.69	.57	28.55	37.46	18.10
15 New York Market	20	.62	.43	48.65	55.5	20.22
16 New Amsterdam forcing	20	.69	.43	38.07	48.10	26.36
17 Danvers Half long	20	.56	.43	58.95	65.00	30.72
18 Henderson's Coreless	20	.98	.47	22.09	50.86	9.76
19 Scarlet Nantes	30	.79	.22	9.13	17.00	2.03
20 (1) de Croissy amelioree	30	.84	.27	10.43	21.46	2.36
21 demi-longue de Carentan	30	.51	.10	4.14	15.57	1.56
22 demi-longue d'Amsterdam	30	.67	.22	10.49	22.43	4.76
23 rouge amelioree a forcer	30	.8	.2	7.47	15.12	1.77

(1) 20 - 23 are French varieties grown in the greenhouse.

Table I (continued).

Variety of Parsnip	No.	D root	D core	(D root)^2	(D core)^2	% core
Offenham Market	20	1.41	.62	1.98	.38	19.19
Delmonico	20	1.39	.66	1.93	.43	22.38
Devonshire	20	1.7	.65	2.89	.42	14.53
New French	20	1.35	.59	1.82	.35	19.23
Hollow Hub	20	1.75	.85	3.06	.72	23.53
Arlington Long Smooth	20	1.35	.66	1.82	.43	29.12
New Kenway's Don	20	1.5	.7	2.25	.47	21.77
Maltese	20	1.16	.66	1.19	.43	36.13
Long White Dutch	20	1.8	.86	3.24	.74	22.84

Table II.

Proportion of Core to Cortex.

(Variety Henherson's Coreless)

D of root in.	D of core in.	$(D \text{ of root})^2$ in.	$(D \text{ of core})^2$ in.	per cent core %
1.10	.42	1.21	.1764	14.57
1.30	.42	1.69	.1764	10.43
1.20	.50	1.44	.25	17.37
1.07	.50	1.14	.25	21.92
.90	.40	.81	.16	19.75
.80	.25	.64	.0625	9.76
1.00	.40	1.00	.16	16.00
.90	.50	.81	.25	30.86
1.00	.42	1.00	.1764	17.64
.80	.42	.64	.1764	27.56
.90	.50	.81	.25	30.86
1.45	.60	2.10	.36	17.14
.90	.50	.81	.25	30.86
.80	.42	.64	.1764	27.56
.90	.42	.81	.1764	21.78
1.00	.42	1.00	.1764	17.64
.90	.40	.81	.16	19.75
.75	.40	.5625	.16	28.44
Av .98	.47	.9606	.2209	22.91

IV. CHEMICAL COMPOSITION OF CARROTS.

One of the important factors which determine the food value of carrots is the chemical composition. Data on the composition give a basis for discussing their value in supplying proteins, carbohydrates, fats, and mineral matter for use in building tissue, and supplying energy. The composition of the carrot is given by the different authorities as follows :

Table III.

Chemical Composition of Carrots.

Water	87.5	88.2	86.8	87.35	88.3	91.54	88.36	90.05
Total nitrogen	.18	--	--	.17	--	---	----	--
Protein	1.1	1.1	1.2	-	1.2	.86	1.19	.88
Fat	---	.4	.3	.20	.2	.07	.14	.18
Cane sugar	3.6	-	2.1	-	-	-	-	-
Fruit sugar	3.0	4.1	-	-	-	-	-	-
Other carbohydrates	4.0		5.0	-	-	-	-	-
Total carbohydrates	10.6	9.2	10.7	6.54	8.0	5.93	8.37	7.92
Ash	.8	1.1	1.0	.84	1.2	.76	1.04	.92
Crude fiber	----	-	1.5	3.47	1.1	.87	.90	-

The ash content of carrots is approximately one per cent. The eight chemical elements, iron, magnesium, potassium, sodium, chlorine, sulphur, phosphorous, and calcium and their compounds are commonly referred to as the ash constituents. These inorganic materials are important in the metabolism and regulating the general condition of the body. The composition of the ash in per centage of edible portion of the carrot is given in table IV. The calcium and phosphorous contents are the most important and are treated separately in tables V and VI. Other materials are

given for comparison.

Table IV.

Composition of the Ash (1)

Material	CaO	MgO	K_2O	Na_2O	P_2O_5	Cl	S	Fe
Carrot	.077	.034	.35	.13	.10	.036	.025	.0008
Potato	.016	.036	.53	.025	.14	.03	.03	.0013
Turnip	.089	.028	.40	.08	.117	.04	.07	.0005
Cabbage	.068	.026	.45	.05	.09	.03	.07	.0011

Table V.

Approximate Amount of P_2O_5.(1)

Material	P_2O_5 per 100 gm. edible substance.	P_2O_5 per 100 gm. Protein	P_2O_5 per 3,000 calories
	gm	gm	gm
Carrot	.10	9.5	6.3
Parsnip	.19	11.2	8.7
Potatoes	.14	6.5	4.7
Turnip	.12	9.2	6.5
Milk	.215	6.4	9.0

Table VI

Approximate Amount of CaO (1)

Material	CaO per 100 gm edible substance gms.	CaO per 100 gm protein gms.	CaO per 3,000 calories gms.
Carrot	.08	7.6	5.2
Potatoes	.02	9.0	.7
Parsnips	.09	5.3	4.1
Turnip	.09	6.9	6.4
Milk	.17	5.1	7.2

(1) Sherman, H.C.--Chemistry of Food and Nutrition. 1918.

There is quite a variation in chemical composition in the different varieties as may be shown by the following tables.(1)

Table VII.

Variety	Water	Dry Matter	Sugar
Half Long Chantenay	88.444	11.56	3.36
Ontario Champion	89.17	10.83	3.19
White Belgian	89.63	10.37	2.06
Mammoth White Intermediate	89.90	10.10	2.08
Mammoth Intermediate	90.00	10.00	1.75
Improved Short White	90.46	9.54	1.38

Also the composition varies from year to year depending on the conditions under which the carrots were grown. This may be seen from the following table which gives the average composition of the same variety for a period of five years, 1905 to 1909.(1)

Table VIII.

Year	Dry matter	Sugar
1905	10.25	2.52
1906	10.59	3.36
1907	10.30	3.02
1908	10.89	3.54
1909	10.40	2.30

Carrots, since they contain a larger quantity of water than some of the starchy vegetables, are lower in nutritive value pound for pound. The water content is approximately the same as in milk and the total dry matter is about half that in potatoes.

(1) Shutt, Frank T.--Can. Farm Rpt. 1900. Analysis of Carrots.

The nitrogenous material is also low, 1.4 to 1.8 % and not all of this in the form of true protein. About half the nitrogenous matter is albuminoid. Carrots contain on the average 9.3 % carbohydrate, including 1.13 % crude fiber. The remainder is sugar and starch, and to these constituents is due the chief value of carrots as a food. One half the total solid matter of the carrot is in the form of sugar, 50 % of this being sucrose and 50 % other sugars, chiefly fruit sugar. The fat content is low as in the case of most vegetables of this nature. The average fat content is .2 - .4 % which is greater than that found in the potato. Besides the protein (tissue building), the carbohydrates and fat (energy producing) of a food, the mineral substances must also be taken into consideration. Iron is needed in making red blood (Hemoglobin), and calcium in making bone. Carrots are relatively high in both of these elements and are valuable on this account.

Carrots, in common with many of the other succulent root crops contain substances which give them a characteristic color, odor, or flavor. This is due to the sugars, plant acids, and to small quantities of volatile oils. Many fleshy roots, especially the carrot, contain together with the cellulose in the cell wall, a substance known as pectin. The color of the carrot is due to a compound known as carotin ($C_{40}H_{56}$). Both carotin and pectin are extracted and used for commercial purposes.

VI. COMPOSITION OF THE CORE AND CORTEX OF CARROT.

As shown by the following tables great variation exists between the core and cortex as to the amounts of nutrients. This has an important bearing on the food value and economy, since

the core is rather low in the important food nutrients. This variation is greater in some varieties than others and is also influenced by the season and the length of the growing period.

A German investigator (1) has analyzed the different parts of the carrot. The results of this analysis are summarized in table IX.

Table IX.

The Distribution of the Nutrients in Carrot.

Part of root	Dry matter %	Nitrogen-free-ext. %
Top	16.1	7.6
Neck		
outer	14.3	8.0
inner	12.2	6.4
Root, upper part		
outer	15.3	7.7
inner	11.5	6.1
innermost core	6.4	1.8
Root, second part		
outer	15.3	8.0
inner	11.6	6.3
innermost core	9.6	2.9
Root, third part		
outer	15.6	8.2
inner	11.9	6.4
Root, fourth lower part		
outer	14.5	8.5
inner	13.5	7.4

The table shows that there is a slight increase in total carbohydrates and dry matter from the crown to the tip of the root; however this variation is too slight to be of any conse-

(1) Zdetstorf and Beger - Fuhlings Landw. Zeit. 53 (1904)

quence. But in a cross section the variation is different. Here there is a marked decrease from the outer layer or cortex to the innermost core. The variation of the soluble carbohydrates is greater than that of the dry matter, amounting in some cases to over five per cent of the total eight per cent. This knowledge of the distribution of the important food materials is valuable to the breeder who undertakes to improve the carrot in respect to the food value.

In order to verify the work of others and to gain additional information along this line, the author made several analyses of the two parts of the carrot. The three varieties selected for this work are all grown commercially in this country. One was a large half long type with a very large core, one a long slender type with small core and the third a half long with medium sized core. The roots were taken from the field, washed thoroughly and separated into core and cortex. As previously stated under the heading of structure the division between the core and cortex is very distinct so that the two parts are easily separated. The pieces were ground in a meat chopper, air dried and a homogeneous sample taken for analyses during the winter. The moisture determinations were made from the fresh sample at the time of harvesting by drying to constant weight at 100° C. All the other determinations were made from the air dry sample and converted into percentages of fresh material. The methods used were those of proximate analysis, according to which residue on burning to whiteness is calculated as ash, total nitrogen multiplied by 6.25 as protein, material soluble in ether as fat, and the residual material (estimated by difference) as carbohydrate. The crude fiber was differentiated from the carbohydrate by boiling with dilute acid and alkali.

The samples were burned to whiteness in a small crucible over a low bunsen flame;the residue weighed and calculated as ash.The total nitrogen was determined by the Kjeldahl method as follows:decomposing the sample with strong sulphuric acid,with the addition of potassium sulphate and copper sulphate which assist in the reaction.When decomposition is complete,the nitrogen remains as ammonium sulphate in the sulphuric acid.After digestion in the Kjeldahl flask,the ammonia is liberated by means of fixed alkali and determined by distilling into standard acid.Since protein is 16% nitrogen,the total nitrogen multiplied by 6.25 gives the total protein in the sample.

For the fat determination a moisture free sample was treated in a Soxhlet extractor with low boiling ether for four hours,the ether evaporated and the residue weighed as fat.The ether was boiled over an electric heater and syphoned over the sample every fifteen minutes.The residue from the fat determinations were used for the crude fiber determinations.The residue was boiled in 1.25 % sulphuric acid for 30 minutes,filtered,washed free from acid and boiled for 30 minutes in 1.25 % sodium hydroxide.This was filtered on a Gooch crucible,washed until neutral,dried at 110°C, weighed,and burned completely.The loss in weight is crude fiber.

The total carbohydrates or nitrogen free extract, including sugars and starch were determined by difference in weight between the original and the total weights of the five previous determinations.

The summarized table below gives the results of the author's analyses of the most important nutritive materials of the core and cortex of the carrot.

Table X.

Composition of the Core and Cortex of Carrot.

Variety	Part	Water	Prot.	Fiber	Carbo.	Fat	Ash
Salzer's	core	91.5	1.46	1.13	5.10	.14	.67
Coreless	cortex	89.45	2.05	.96	7.11	.41	1.02
Early							
Scarlet Horn	core	92.2	1.08	1.6	4.03	.21	.88
	cortex	89.8	1.28	.85	6.41	.33	1.23
Henderson's	core	90.0	.85	1.3[illegible]	6.77	.14	.87
Coreless	cortex	87.45	1.43	.98	8.73	.34	1.07

By these analyses the author has conclusively shown that the distribution of the important food constituents is not uniform in a cross section. In case of the protein, fat, ash, and carbohydrates the higher proportion is found in the outer layer while the inner layer is much lower. However the larger amount of crude fiber and water is found in the central portion. This is to be expected since an examination shows the core to be of a more or less woody texture. Of the total sugars present approximately 3[illegible] % more is deposited in the outer layer. (author's analyses).

VII. THE NUTRITIVE VALUE OF CARROTS.

A food may be defined as a substance which will supply energy, provide for growth, and repair the tissue waste of the organism. The energy expended by the body is chiefly derived from the burning of organic materials, especially carbohydrates, proteins, and fat.

The nutritive value of a food is indicated by its chemical composition, behavior in digestion and metabolism. In many cases the chemical composition alone is used as a basis for the food value. This is obtained by the proximate analysis using the conventional methods described on page 16 and 17.

The behavior of a food in digestion has to do with the digestibility of the food itself and the influence of the food upon the digestive process. Of the three important materials, the proteins are the least completely absorbed by the body. On a purely vegetable diet, the loss may be very great, as in the case of carrots as much as 40 % of the total protein consumed. The fats are more completely absorbed than the proteins and the absorption of carbohydrates is the most perfect of all. Digestibility trials of a food are natural or artificial, that is the food may be actually fed to man and the per cent determined or it may be treated with the various digestive solutions.

Table XI.

Digestibility of Carrots + Fat. (1)

	Solids	Nitrogen	Fat	Carbohydrates	Ash
Ingredients in the food . gms.	411.6	6.6	47.3	281.9	41.2
Ingredients in the feces. gms.	85.1	2.5	3.1	-	14.0
Food ingredients undigested. %	20.7	39.0	6.4	18.2	33.0

(1) Snyder, Frisby, Bryant --U.S.D.A. Off. Exp. Sta. Bul. 43

The calorie is the unit of measure for the amount of energy of a food. The calorific value or heat of combustion of any substance, that is the amount of energy liberated by the burning of a given quantity of the combustible material, is determined by means of the bomb calorimeter. Since the body gets its energy from the oxidation of the compounds in foods, chiefly proteins, fats, and carbohydrates, if we know the kinds and amounts of foodstuffs eaten and the extent and the extent to which they are oxidized in the body we can determine in terms of calories, the amount of energy liberated. The average heats of combustion are :

Carbohydrates	4.1	calories	per	gram
Fats	9.45	"	"	"
Proteins	5.65	"	"	"

However proteins yield products which are eliminated as end products and must be excreted so that 1.3 calories per gram are lost leaving 4.35 calories per gram. After deducting the amount of the material lost in digestion we have the following:

Carbohydrates	4.0	calories	per	gram
Fats	9.0.	"	"	"
Protein	4.0	"	"	"

Thus in the case of carrots, with the composition 1.1 % protein, .4 % fat and 9.2% carbohydrates, 100 grams furnish 4.4 calories of protein, 1.6 of fat and 37.2 of carbohydrates, making a total of 43.2 calories per 100 grams of the material.

However it should be emphasized that the fuel value of a food, while of primary importance, is not alone a complete measurement of its nutritive value, which will depend in part also upon the amounts and form of nitrogen, phosphorous, iron, and other important elements furnished by a food.

The principal food substances needed in the diet are starch, sugar, vegetable acids, fiber, fat, protein and mineral substances. Carrots, although they contain a high percentage of water are a common source of many substances needed in the body in small amounts, and in addition hold in their fluids, acids and alkali which are important in keeping the body in good condition. They are therefore an important food from the stand point of growth and health.

One of the fundamental facts in the economy of of a food is that the difference in the value of the different foods depends upon both the kinds and amounts of the nutrient materials which they contain. It is essential for health that the food shall supply nutrients in the kinds and proportions required by the body.

In order to determine the utilization of the calcium of carrots by the human body, two series of experiments have been carried out on four healthy young women.(24) Calcium is one of the important elements required by the body and is important in the formation of bone. Carrots are relatively high in this respect. The calcium intake was in every case close to the estimated minimum for equilibrium.

Table XII.

Average Daily Intake and Output of Calcium.

Series	Diet	Av. Daily Intake of Calcium gms	Calcium From carrot %	av. daily output urine gm	av. daily output feces gm	Balance	Gain or loss %
I	Milk	0.383	-	..070	.254	+.060	+15.6
I	Carrot	0.315	55	.058	.202	+.055	+17.4
I	Milk	0.383	-	.069	.226	+.087	+22.7
I	Carrot	0.315	55	.075	.262	-.023	-7.3
II	Carrot	0.261	84	.071	.180	+.010	+ 3.8
II	Carrot	0.300	86	.065	.152	+.082	+26.6

In all case but one there was a positive calcium balance on the carrot diet, and in that case the loss was small. When approximately 55% of the calcium was derived from the carrot, one subject had practically the same retention as on a diet in which 70% of the calcium was derived from milk. It seems possible therefore to meet the requirement of the human adult organism for calcium largely, if not wholly from carrots.

The carrot is valuable in itself as a cooked vegetable and is also used to give flavor to other dishes. When partially mature and fresh from the ground they have a delicious flavor and are so tender that they may be cooked without water. However as the carrot grows older the flavor become stronger and in most cases the core becomes fiberous and woody. When the carrot reaches this stage only the outer layers are desirable for food.

Carrots are cooked in many ways in the fresh state and are quite generally liked. In addition they are often found on the market in the dessicated form and are also canned in the same way as other vegetables.

The committee for the control of foodstuffs attached to the office of the food controller in the United Kingdom drew the attention of the public, during the war to the high food value of carrots. It was pointed out that three pounds of carrots were equivalent to two pounds of potatoes, one of veal or chicken, one of bread, six of tomatoes, or six or eight eggs.

Another important consideration in determining the food value of any material is its vitamin content. Although little is known at present about the nature of vitamines, much has been learned concerning their relation to health and disease.

There are three distinct kinds of vitamins;namely,the fat-soluble A, or antixerophthalmic,which is found chiefly in certain fats,the water-soluble B , or antineuritic,and the water-soluble C,or antiscorbutic.These are commonly referred to as vitamine A,B,or C. Lack of vitamine A in the diet results in xerophthalmia,a disease of the eye ,often resulting in blindness,lack of B in the disease known as berri-berri,sterility,and other complications,while lack of C causes scurvy.

It has been found that root crops,especially carrots,are well supplied with vitamins and may be classed with the green leafy vegetables in this respect rather than with the cereals. (1)Carrots are rich in vitamine A,rich in B,anf fair in C(2).In feeding trials (1)carrots were found to be remarkably rich in the fat-soluble vitamine and sufficient quantities of both the fat - and the water soluble were furnished by a diet of 15 % carrots. The authors concluded that the practice of feeding carrots in lieu of green material which is in vogue by many small animal breeders, is dietitically justified from the standpoint of vitamins alone. They also concluded that this is possibly the experimental justification for the use of carrot juice as an adjuvant to the boiled milk diet of children.It is a common belief that raw carrots are healthful for young children and this may be explained by the fact that carrots are fairly rich in vitamine C which prevents scurvy, and also helps to promote growth.Raw carrots may then be healthful for children because vitamine C is practically destroyed upon cooking.A and B,however, are mostly retained in the process of cooking.

(1)Steenbockand Cross -J.Biol.Chem.40(1919)Fat-Soluble Vitamine Content of Roots.
(2)Read,Palmer,Steer-Ark.Bul.176 -Vitamins in the Diet.

Cooking trials were made by the author of the different parts of the root ,in order to determine the relative strength of the flavor in the outer and inner portion.The roots were young and in the proper stage of growth.In every case the outer layer was of better flavor than either the inner layer or both cooked together.There was not so great a difference in the texture of these two parts as there was in the flavor.This was probably due to the fact that in the earlier stage the care had not reached the fi fiberous,woody condition.However the core was very poor in flavor and in fact was nearly tasteless,while the cortex was sweet,tender, and not in the least strong,thus showing that there was no need of the core to dilute the flavor and confirming the previous conclusions that the greater part of the sugar and other food materials was stored in the cortex.

VIII.CHEMICAL COMPOSITION OF THE PARSNIP.

The chemical composition of the parsnip is very similar to that of the carrot except that the amount of the solid material is greater and the nutrients are in somewhat different form.The composition is given as follows(Different authorities)

Table XIII.

Composition of the Parsnip (1).

Water	Ash	Protein	Fiber	Carbohydrate	Fat
83.4	1.3	1.7	1.3	11.9	.4
83.0	1.4	1.6	2.5	11.0	.5

(1)Sherman,H.C.--Chemistry of Food and Nutrition 1918.

Table XIV.

Composition of the Ash. (1)

Material	CaO	MgO	K_2O	Na_2O	P_2O_5	Cl	S	Fe
Parsnip	.14	.11	1.07	.02	.29	.05	-	-
Potato	.016	.036	.53	.025	.14	.03	.03	.0013
Turnip	.089	.028	.40	.08	.117	.04	.07	.0005
Cabbage	.068	.026	.45	.05	.09	.03	.07	.0011

Table XV.

Approximate Amount of P_2O_5. (1)

Material	P_2O_5 per 100 gms edible portion	P_2O_5 per 100 gms protein	P_2O_5 per 3,000 calories
Parsnip	.19	11.2	8.7
Potato	.14	6.5	4.7
Turnip	.12	9.2	8.5
Milk	.215	6.4	9.0

Table XVI.

Approximate Amount of K_2O. (2)

Material	K_2O per 100 gms edible portion	K_2O per 100 gms protein	K_2O per 3,000 Calories
Parsnip	.695	43.1	32.10
Potato	.525	23.6	18.90
Turnip	.400	44.4	30.00
Milk	.168	5.1	7.29

(1) Sherman ,H.C. +-Chemistry of Food and Nutrition 1918

(2) Calculated from table XIV.

It can be seen from the above tables that the parsnip furnishes large amounts of mineral salts, especially potassium, calcium, magnesium, and phosphorous. All of these materials are used in the body in small amounts for the building of tissue, repair of waste, for the proper carrying out of the physiological functions, and to insure a sufficiency of alkaline ash substances for body needs. The parsnip does not contain iron and sulphur and in this respect is not as good as the carrot which is relatively high in these materials.

Parsnips contain more dry matter than carrots and have practically the same amounts of nitrogen and fat. The carbohydrates are greater but there is less sugar and more starch. The crude fiber content is greater in most varieties especially in the core which is rather woody.

As already stated there is a great variation of the nutrients in the cortex and central cylinder of the root. This variation is greater in some varieties than in others, and may also depend on the season and the length of the growing period. The difference in the composition of the two parts was worked out by Vollecher in 1853 (1) as follows. By moistening a transverse section of the root with tincture of iodine, the external layers are colored a deep blue, while the inner portion is only slightly colored. By this means three distinct circles can be distinguished on a transverse section: one interior formed by the heart of the root, an exterior colored deep blue by the production of iodide of starch and an intermediate circle between the heart and the exterior dark colored zone. This distinctly shows that the starch does not exist in the heart,

(1) Vollcker, Agustus-J, Roy. Ag. Soc. V. 13 --Analyses of Parsnips.

nor in the layer next to it, but that it is all deposited in the external layers of the root. In the case of protein the intermediate layer contains a higher amount than either the heart or the outer layer, where the starch was deposited. The intermediate portion between the heart and the outer layer contain one half more flesh forming constituents than the other portions of the root.

Table XVII.

	Outer	Heart	Intermediate
% Nitrogen	1.039	1.067	1.5
% Protein	6.493	6.66	9.395

Analyses of two varieties of parsnips by the author confirmed the work of others, that the cortex contained a larger part of the nutrients. Another important point brought out by the analyses was the large variation in the chemical composition in the two varieties. The samples were prepared in the same way as in the case of carrots and the methods of analysis were the same. The varieties used were New Kenways Don and Hollow Crown which seemed to be representative types of the fifteen varieties in the plot. The following table gives the summary of these analyses:

Table XVIII.

Chemical Composition of the Parsnip.

Variety	Part	Water	Prot	Fiber	Carbo.	Fat	Ash
New Kenways Don	core	85.7	1.51	4.48	7.10	.35	.86
	cortex	82.4	1.86	3.04	10.85	.46	1.39
Hollow crown	core	82.2	.79	3.25	12.39	.41	.96
	cortex	80.7	1.45	1.73	14.41	.49	1.22

From the table it can be seen that the greatest variation is in the crude fiber, both between varieties and between the core and cortex of the same variety. The parsnip contains quite a little more cellulose material than the carrot, as would be expected since the texture has the appearance of being rather stringy and fiberous, especially in the core. The core contains from 2 to 3 per cent more water than the cortex. In all other respects the cortex has the higher per cent of materials, the difference varying from .1 % in the case of the fat to 2 to 3 % in the soluble carbohydrates. Therefore in the parsnip, as in the carrot, the distribution of the important food materials is not uniform in a cross section.

IX. NUTRITIVE VALUE OF THE PARSNIP.

The parsnip, because of its pronounced flavor is probably not so generally liked as the carrot or most of the other root crops of this class. However when cooked long enough parsnips form a good food. The roots are boiled, fried, and in some cases used in soups and stews. In Europe boiled parsnips are considered to be the proper vegetable to serve with salt fish. In America they are served boiled or fried with roast meats of any sort.

One of the chief reasons for the popularity of the potato over such crops as carrots and parsnips is its lack of flavor, which makes it possible to confer palatibility upon it by the addition of seasoning materials such as butter or cream. Neither parsnips nor carrots could become as popular as a regular article of diet because of their pronounced flavor, which does not appeal to the appetite when used regularly in the diet. They are, however valuable as supplements.

Like the carrot, the parsnip contains a large proportion of water and considerable starch and sugar. Generally speaking the food value of the parsnip is about the same as the carrot but due to the higher amount of dry matter the parsnip is slightly higher in calorific value. The amounts of protein, fat and ash are about the same in both but the amount of carbohydrates is higher in the parsnip. The larger part is starch instead of sugar, as in the case of the carrot. The parsnip contains a larger amount of cellulose particularly in the core, which becomes stringy and woody when the roots are old. Cellulose is practically indigestible but is not objectionable when present in small amounts. Probably its sole use is to serve as structure building material. It is undoubtedly elaborated from the carbohydrates as the cell grows. In only rare cases, however, is there evidence that it can be reconverted into soluble carbohydrates to serve as food materials. Its chief use in the diet is to contribute bulk to the food.

Parsnips may be kept in the ground for a large part of the winter and are easily stored since they are not affected by freezing. Many people believe the root to be poisonous if eaten after growth has started in the spring but this belief is probably without foundation as there seems to be no evidence that a poisonous principal is elaborated. The quality of the parsnip is somewhat improved by leaving the roots in the ground over winter. In the spring these roots are an addition to the diet because most of the stored root crops are beginning to lose their flavor and good texture.

Both on account of their fattening qualities, (since they contain nearly a third more carbohydrate material than

the carrot ,and because they can be easily stored ,parsnips are also valuable for stock feeding.This is especially true in the early spring when the supply of fresh succulent food is likely to be short.They are relished by cattle and highly esteemed by many European farmers for fattening purposes if they can be economically grown.However neither the carrot nor the parsnip is important in the corn belt of the United States as a stock food, ~~because of the adverse climatic conditions.~~

X.LOSSES IN COOKING.

Ordinary methods of cooking do not perceptibly injure the nutritive value of carrots,at least not when they are used as part of a mixed diet.However a considerable portion of the calorific value of the food is lost when the water used in cooking them is discarded.When carrots are boiled in water the loss of mineral and nitrogenous material and also of sugar is large,the amount depending on the sizes of the pieces into which the carrots are cut.The following table illustrates the fact.

Table XIX.

Loss of Nutrients in Cooking.

Size of piece	Nitrogenous loss %	Sugar loss %
Large	20	15
Medium	27	26
Small	40	26

Table XX .

Loss of Mineral Material in Cooking .

Method	Solids %	Ash %	P_2O_5 %	CaO %	MgO %
cut up, boiled	10.05	11.48	22.88	10.88	19.19
boiled whole	6.25	7.38	17.97	8.77	19.19
cut up, boiled	-	6.91	15.84	.25	8.01
boiled whole	-	4.90	12.46	2.61	14.42

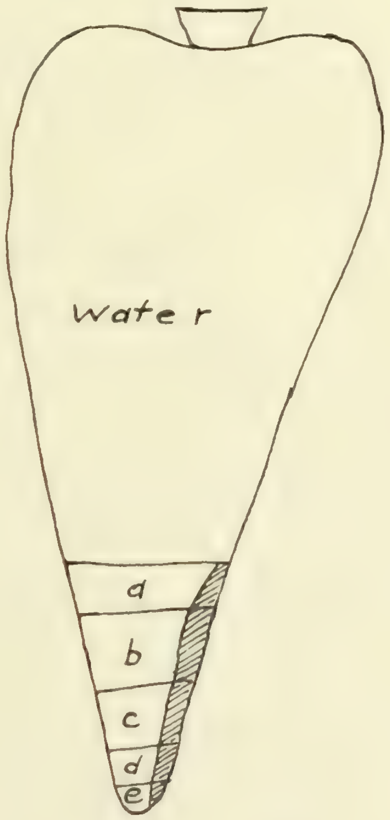

Figure 2

Composition and loss (shaded portion)

of nutrients in carrot.

a - fiber ;starch,fat; b - sugar

c - non-proteid nitrogen:d - proteid

nitrogen;e - mineral .

The water in which carrots have been boiled is quite yellow and has a sweetish taste, showing that some of the nutrients have been lost in the process of cooking. The temperature of the water makes very little difference in the amount lost. However the more water used the greater the loss and the more rapidly the carrots are boiled the smaller the loss. It has also been found that when carrots are steamed they become soft a little more quickly than when cooked in hot water, and so lose less material.

The amounts of nutritive material lost from parsnips in cooking is not definitely known but it is probably considerable. The amount is certainly affected by the same conditions as in the case of carrots.

XI. ECONOMIC VALUE OF CARROTS AND PARSNIPS.

The first factor in determining the economy of a food is its cheapness as a source of feul. Table XXI shows the cost of carrots and parsnips as compared with potatoes in terms of calories. The figures are based on the New York wholesale market for the month of November for the years 1917 - 1921 inclusive.

Table XXI.

Cost of Carrots and Parsnips as Food.

	Cost per bu.	Calories per bu.	Cost per 3,000 Cal.
Carrot	$.75	10,500	$ .21
Parsnip	1.17	14,700	.23
Potato	1.58	22,680	.21

Thus the price per bushel for carrots is half that of potatoes and one-third less for parsnips. Due to the lower nutritive value pound for pound neither contains as many calories per bushel but the cost per 3,000 calories is the same in the case of carrots and slightly higher in the case of parsnips as compared with potatoes. Carrots and parsnips are therefore practically as cheap a source of food as potatoes.

Another factor must be taken into consideration, namely the yield of each crop per unit of area. Unless this is done, erroneous conclusions are bound to occur. For example the food value of carrots is 55 % of that of the potato. This is true in the sense that there are 55 as many calories in a pound of carrots as in a pound of potatoes. However, when we consider the number of calories produced by an acre of ground under potatoes as compared to that provided by an equal area of ground under carrots we find that the same ratio does not exist.

Table XXII.

Calories of Carrots and Parsnips Produced on an Acre.

Crop	Yield per acre lbs. (1)	Lbs dry matter lbs.	Cal. per lb. (2)	Cal per acre
Potato	13,550	3,140	385	5,216,750
Carrot	37,000	6,364	210	7,770,000
Parsnip	26,966	4,586	300	8,089,800

(1) Average of several reports.
(2) U.S.D.A.Off.Exp.Sta.Bul.28.

The higher yields obtained from carrots and parsnips are more than enough to make up for the lower nutritive value and therefore more calories are produced from an acre of ground.

Another consideration of economic importance which usually escapes notice is that the different varieties of the same vegetable differ widely in chemical composition and therefore in food value. In the case of carrots and parsnips this difference is chiefly due to two factors, the proportion of core to cortex and the composition of the core and cortex. Since the core is much lower in nutritive value than the cortex, the larger the proportion of core the lower the food value, and also the higher the cost per calorie. The calorific value of some of the different varieties of carrots and parsnips may be seen from the following tables.

Table XXIII.

Calorific Value of a Bushel of Different Varieties of Carrots.

Variety	lbs in core	lbs in cortex	Cal. in core	Cal. in cortex	Total Cal.	Cost per 3,000 cal.
Salzer's Coreless	26.4	33.6	3,986.4	6,081.6	10,068	$ .22
Early Scarlet Horn	24.	36.	3,192.0	5,976.0	9,168	.24
Henderson's Coreless	10.8	49.2	1,890.0	11,020.8	12.910.	.17

Table XXIV.

Calorific Value of a Bushel of Different Varieties of Parsnips.

Variety	lbs in core	lbs in cortex	Cal. in core	Cal. in cortex	Total Cal.	Cost per 3,000 cal.
New Kenways Don	13.2	46.8	2,296.8	11,882	14,178	$ .24
Hollow Crown	19.2	40.8	4,838.4	12,729	17,567	.20

A difference of four cents per 3,000 calories exists between two varieties of parsnips and seven between two of carrots. Assuming that roots with a small core would produce as large a yield as those with larger cores, the smaller the core the more economical the root. There is need of data regarding the comparative yields of such varieties. Strains of the highest degree of quality should be selected.

XII. CONDITIONS WHICH EFFECT THE COMPOSITION.

There are several factors which have an effect on the composition of root crops and therefore on their food value. The most important of theseare breeding and selection, cultural methods and storage.

The importance of the effects of breeding and selection on the composition have been brought out by a study of the distribution of the food materials in the root and also the proportion of core and cortex existing there. Since the greater part of the nutrients are stored in the cortex any improvement of the variety by breeding or selection whereby the proportion of cortex was increased would be of material value. This can be seen from a comparison of some of the French and American varieties of carrots. The last four varieties in table X, which were obtained from France, are characterized by a small core which plainly shows the importance of selection on the value of the crop.

The effect of the culture of the crop while of some significance is not as important as that of selection. It has been demonstrated that a long growing season tends to produce a root with a large per cent of fiberous material and strong flavor.

This is especially true of carrots since parsnips normally take a longer growing season. The stronger flavor is objectionable since the roots have a strong flavor at best. The increased amount of fiberous material could not add to the value of the crop since it is chiefly cellulose which is practically or wholly indigestible and therefore of no value when in excess of the normal amount. From this we would conclude that any condition whereby a rapid growth could be secured would produce a root of higher value. That is to say moisture, cultivation, and soil conditions have an important effect on the composition and value of the crop.

When roots are stored they tend to become dry, fiberous and tasteless. These changes are due to the natural processes of transpiration and respiration. Unless ideal conditions are provided the effects of evaporation, fungi, and bacteria on the composition and quality of the crop may be serious.

In experiments at Vermont (1) different media and kinds of storage were tried out on carrots and parsnips. In cold storage at 38°F. after six and one half months a large part of the parsnips were in good condition while 60 % of the carrots were rotted. In common cellar storage none of the carrots were edible and only 61 % of the parsnips. Roots stored under living room conditions were all inedible. Of the different media trials, dry sand gave the best results. Of the disinfectants Bordeaux was superior. Moisture determinations showed that roots packed in dry sand lost in weight, that those packed in moist media gained, and that those treated with a disinfectant lost in weight. The moisture losses observed were not commensurate with those obtained by chemical analysis, which would show that much of the loss in weight

(1) Aldrich, F.H.- Vt. Bul. 203 - Winter Storage of Roots.

occurring during storage is oxidized dry matter.

Roots stored by the author under the various methods resulted in the same conclusions which can be seen from the follwoing table. The roots were placed in storage September 27 and removed December 19. Carrots and parsnips were stored in three ways; exposed to air, buried in sand, and stored in outdoor pit. The roots exposed to air were kept in a common cellar at a temperature of 45 to 50 $^{\circ}$ F. The sand stored roots were in the same cellar but were placed between alternate layers of sand in a bushel box. The pit storage system consisted of an outdoor surface pit with drainage and alternate layers of dirt and straw, with a temperature slightly above freezing. The loss in weight was determined in two ways, weight of the roots before and after storage and by chemical analysis.

Table XXV.

Loss in Weight During Storage.

Treatment	Wt. Before oz	Wt. after oz	Loss in Wt. oz	Loss %
Air				
Carrots	168.5	59.0	109.5	64
Parsnips	128.0	43.0	85.	66
Pit				
Carrots	163.	156.	7.	4.3
Parsnip	175.	156.	19.	10.6
Sand				
Carrots	163.5	156.	7.	4.3
Parsnip	124.	120.	4.	3.2

In both pit and sand storage the roots were in excellent condition when removed. There was little or no disease present and the roots were firm and fresh. However, in case of those roots exposed to air in the cellar the reverse was true. All were shriveled and practically inedible. Chemical analysis showed a loss of moisture of 24 % for those exposed, 3 % for pit storage, and 2 % for those buried in sand.

Edibility trials showed that when cooked those roots exposed to the air were tough and tasteless as compared to those stored in sand or outdoor pit. The latter were of good flavor and quality. There seems to be an increase in the amount of fiberous material towards the end of the storage period which is probably due to the thickened tracheal tubes.

There is very little actual loss of food nutrients in storage. Experiments tend to show that outside of loss of moisture and change in the form of the carbohydrates there is very little change during storage. Analyses at the Canada Experimental Farms (1) gave the following results.

Table XXVI.

Loss in Storage.

Date of analysis	Improved Short White Water	Improved Short White Dry matter	Oxheart Water	Oxheart Dry matter
Oct.27	91.54	8.46	88.36	11.64
Jan.15	89.49	1 .51	89.55	10.45
Mar.15	9 /27	9.73	89.35	10.65

(1) Shutts, Frank T.-- Can.Ex.Farm Rpt/1901 - Changes in the Composition of Root Crops During Storage.

Table XXVII

Loss of Nitrates in Dry Matter.

Date of analysis	Improved Short White Total nit.	Alb.nit	non-alb.	Oxheart Total nit.	alb.nit.	non-alb.
Oct.27	1.17	.75	.42	1.53	.91	.62
Dec.15	1.03	.59	.44	1.62	.75	.87
Jan.15	1.39	.75	.64	1.76	.84	.92

Although there is little loss of food nutrients during storage, there is a transformation of some of the materials. So far as known there has been no work done in the case of carrots or parsnips to determine the amount and nature of this transformation. However, it is reasonable to assume that the same changes would take place as in similar root crops. The changes taking place in the sweet potato during storage have been worked out by Hasselbring and Hawkins (1). During its growth the sweet potato root is characterized by a very low sugar content. The reserve materials from the vines are almost wholly deposited as starch.

Immediately after the roots are harvested there occurs a rapid transformation of starch into cane and reducing sugar. This initial transformation seems to be due to internal causes and and is largely dependent on external conditions.

Even at a temperature of 30° C. both cane and reducing sugars accumulate during this initial period in excess of the quantity used in respiration, while during subsequent periods the quantity of reducing sugar diminishes at that temperature as a result of respiration. These initial changes seem to be associated with the cessation of the flow of materials from the vines.

(1)Hasselbring and Hawkins -J Ag Res 3;331 -Changes in sweet potato--

In sweet potatoes stored at a temperature of 11.7 - 16.7° C. the moisture remains fairly constant. There is a gradual disappearance of starch during the first part of the period, (Oct to Mar) and probably a reformation of starch accompanied by the disappearance of cane sugar during the latter part (Mar -June)/. The change in reducing sugar is less marked than cane sugar. The changes in starch and cane sugar appear in a general way to be correlated with the seasonal changes in temperature.

Table XXVIII.

Changes in Big Stem Jersey in Farm Cellar.

Date	Water	Starch	Cane Sugar	Reducing Sugar	Total sugar	Total carbohydrates
Oct.20	73.5	19.07	1.9	.9	2.9	24.09
Nov.8	72.99	16.94	3.51	1.32	5.02	23.85
Dec.6	71.89	16.42	3.94	1.4	5.55	23.79
Jan.4	72.06	16.02	4.39	1.28	5.9	23.7
Feb.1	72.18	14.11	6.06	1.67	8.04	23.7
Mar.1	71.97	13.09	6.96	1.44	8.76	23.31
Mar.20	73.02	13.44	6.4	1.1	7.84	22.77
Mar.26	72.49	14.47	5.61	.87	6.77	22.85
Apr.16	72.87	14.2	6.03	.9	7.24	23.02
Jun.1	72.45	14.62	5.85	.87	7.02	23.27

Table XXIX.
Big Stem Jersey in Cold Storage

Date	Water	Starch	Cane sugar	Reducing sugar	Total sugar	Total carbo- hydrates
Nov.8	72.99	16.94	3.51	1.32	5.02	23.85
Dec.9	72.99	13.31	6.46	2.02	8.82	23.62
Dec.20	70.77	10.8	7.33	1.6	9.31	21.31

XIII. SUMMARY.

Carrots and parsnips are classed as succulent root crops because of their high percentage of water, which is 87 to 90 % in carrots and 80 to 84 % in parsnips. Most of the solid material is carbohydrates, in the form of sugar in carrots and starch in parsnips. These roots are characterized by peculiar flavors and odors, due to certain sugars, plant acids, and volatile oils. Because of their marked flavors they cannot be as popular as the potato as a regular article of diet, but are very valuable as supplements.

In general the chemical composition and food value of the carrot and parsnip are the same. Both, since they have a large amount of water and are low in protein and fat, are not as high in food value as some other vegetables. They owe their chief value as food to the relatively high per cent of carbohydrate material. In addition to carbohydrates both are well supplied with mineral salts, chiefly calcium, iron, phosphorous, potassium, and magnesium. These elements are essential to the diet for the building of tissue, formation of bone and blood, and for keeping the body fluids in the

condition necessary for the proper functioning.

Carrots and parsnips are an economic source of food. Although not so high in calorific value pound for pound as potatoes they can be more economically grown and stored, produce higher yields, and are cheaper than potatoes. They owe their importance chiefly to the soluble carbohydrates, to their flavor and odor, which add variety to the diet, to their bulk, which is important from the standpoint of hygene because a certain amount of bulk is needed for normal digestion, and to their mineral salts which are necessary for growth and condition of the body.

The results of the author's work in determining the relative composition of the core and cortex conclusively proves that nearly 50 % more of the important food nutrients are stored in the cortex or outer layer of the root than in the core. Moreover his studies of the various commercial varieties show that a wide variation in proportion of core to cortex exists between individual roots of the same variety and between individuals of different varieties. This wide variation is chiefly due to the matter of selection. Those varieties having a small percentage of core represent the results of continued selection through several generations, while those with a larger percentage of core have been neglected.

Since the cortex contains the largest amount of nutritive materials it is important from an economic standpoint to produce strains or varieties with the smallest core possible. This process is not difficult and if continued for several generations will result in marked improvement. Those roots having the smallest core should be selected in the fall. In order to save only the best, the tip of the root may be cut off, to determine the size of the core.

The cut end should be coated with melted paraffin to avoid rotting during storage. Roots so selected by the author were kept in fair condition in dry sand from September 17 until they were planted Aprril 15. Seed may be grown from the roots and planted the following year for further selection.

In recent years much has beenlearned of the relation of vitamins in the diet to health and disease. Since green leafy vegetables and some of the others as carrots and tomatoes are found to be high in vitamine content, the result has been campaigns and arguments for the increased use of these vegetables in the diet. This campaign should be accompained by increased efforts on the part of experimenters to improve the present strains and varieties, whether the improvement be in the food value or texture. The results of the author's work with the food value of carrots and parsnips shows clearly that great progress can be made in improving the economic value of these vegetables. The same sort of experiment and improvement could be mapped out for many other vegetables, and if horticultural experimenters can keep pace in their improvement of vegetables with the increased interest of the public in their value as food, a great increase both in the quality and consumption of the vegetables must result.

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Signed C.P. Lewis